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First population assessment of the Asian Water Dragon (*Physignathus cocincinus* Cuvier, 1829) in Thua Thien Hue Province, Vietnam

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Abstract

The Asian Water Dragon, *Physignathus cocincinus* Cuvier, 1829, was originally described from southern Vietnam. Wild populations of this species are strongly affected by harvesting, particularly in central Vietnam, while potential negative impacts are not yet foreseeable. This study provides the first population size estimation using a capture-recapture approach and an evaluation of threats to and trade levels in *P. cocincinus* in Thua Thien Hue Province, central Vietnam. Field surveys were conducted at 14 sites of known occurrences of the species in Thua Thien Hue during April and June of 2016 and 2017. The estimated population size of the species amongst these sites ranged from 232 to 250 individuals. The mean abundance varied from 1.98–2.64 individuals/100 m along inhabited streams. This study revealed harvest activities for local food consumption and to supply the pet trade. Accordingly, imports of several thousand living individuals per year from Vietnam into the EU were documented. It was further demonstrated that the level of negative impacts on different sub-populations is in accordance with respective abundances and the incidence of adults. This finding indicates that rising harvest levels in concert with decreasing habitat

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quality, might seriously affect the wild population of *P. cocincinus* in the future. Thus, the authors herein emphasise the necessity for increased conservation measures and for monitoring of the species as well as its natural habitat in order to warrant a sustainable use of the species in the future.

Keywords
Population size, capture-recapture method, trade, conservation, risk assessment

Introduction

The Asian Water Dragon, *Physignathus cocincinus*, was originally described by Cuvier, 1829 from southern Vietnam, subsequently recorded from southern China, Myanmar, Thailand, Laos and Cambodia and reported as introduced in Taiwan (Smith 1935, Taylor 1963, Cox et al. 1998, Nabhitabhata et al. 2000, Stuart and Emmett 2006, Stuart et al. 2006, Grismer et al. 2008a, b, Suzuki et al. 2015, Uetz et al. 2017). Typical habitats of the species consist of undisturbed rocky streams within evergreen lowland rainforest, but sometimes the species can also be found in densely vegetated streams nearby villages and in agricultural areas (Ziegler 2002, Nguyen et al. 2009). In Vietnam, the Asian Water Dragon is considered as a species with a wide geographic range. However, habitat degradation represents an emerging threat and there is rising evidence for strong local use of the species. In addition, its attractive appearance, as well as its semi-aquatic lifestyle, made the species a highly desirable target species in the international pet trade (UNEP-WCMC 2017). As a consequence, the species was recently listed in the Vietnam Red Data Book (2007) as Vulnerable. Furthermore, the species was listed in Appendix D on the "Council Regulation (EC) No. 338/97 on the protection of species of wild fauna and flora by regulating trade therein" in order to identify potential unsustainable levels of trade in the species in good time. However, basic knowledge on the current population status of *P. cocincinus* and anthropogenic impacts on the species is still lacking. Population size estimations provide essential baseline information for the assessment of the conservation status of species and populations and are crucial for wildlife management strategies (Reed et al. 2003, Traill et al. 2007, Ngo et al. 2016). The present study provides the first assessment of the population size of *P. cocincinus* in Vietnam, based on surveys conducted in Thua Thien Hue Province, as well as an evaluation of threats in order to assess its conservation status and as a basis for timely development of adequate conservation management to warrant both the persistence and the sustainable use of the species.

Methods

Study sites

Survey sites were selected based on previous reports on known occurrences of *P. cocincinus* in Phong Dien Nature Reserve (NR) in Phong Dien District, Sao La NR in A

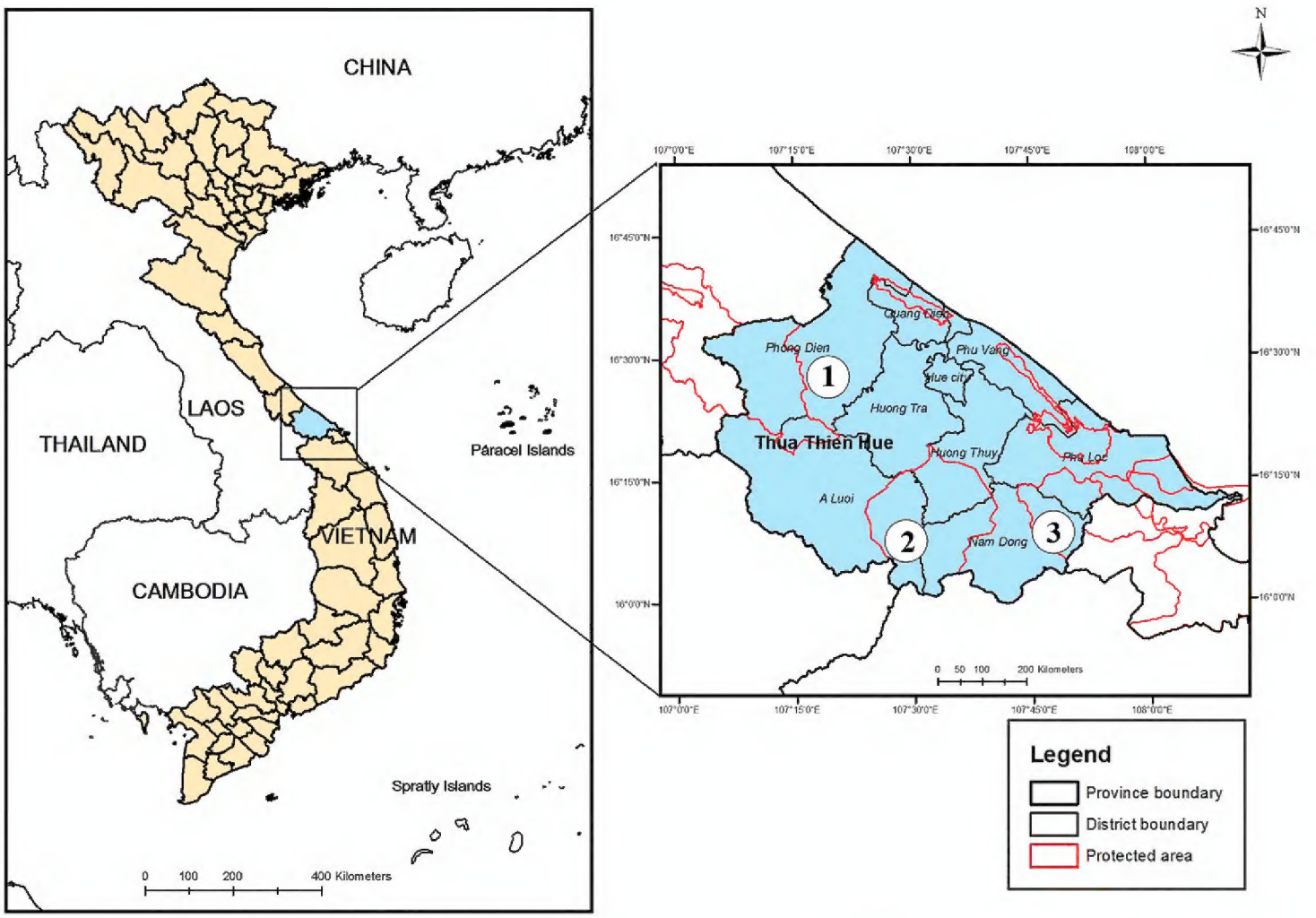

Figure 1. Map of Thua Thien Hue Province in central Vietnam showing the survey sites: **1** Phong Dien NR in Phong Dien District; (2) Sao La NR in A Luoi District; and **3** Bach Ma NP in Nam Dong District.

Luoi District and Bach Ma National Park (NP) in Nam Dong District, Thua Thien Hue Province, Vietnam (Nguyen et al. 2009) (Figure 1). The vegetation throughout the study area is dominated by evergreen broadleaf forest, intermixed with bamboo forest. The region is characterised by a tropical climate and seasonal monsoons, with an annual average temperature of 24.9 ± 0.51 °C, an annual average precipitation of 3243.2 ± 780.6 mm and an annual average humidity of 86.8 ± 1.05% (General Statistics Office of Vietnam 2013, Nguyen et al. 2013).

Field surveys

Field surveys were conducted in April and June 2016 and 2017, respectively, during the active season of the Asian Water Dragon. During previous surveys, *P. cocincinus* was found to be a riparian species, being exclusively recorded in the immediate proximity to or above the water at the stream banks. Thus, the riverine vegetation of selected rocky streams was sampled from downstream to upstream by walking through the water and intensively investigating both sides of the streams equally. The surveyed streams were characterised by a width of about 1–12 m, depths of up to 200 cm and dense vegetation along and above the stream. Since *P. cocincinus* is a diurnal species, night excursions were conducted between 1900h and 2400h, when animals were expected to rest on branches above the water (Fig. 2A).

Figure 2.A Habitat of *Physignathus cocincinus* in Nam Dong District, Thua Thien Hue Province **B** Resting perch in front of waterfall **C** Adult male **D** Adult female. Photos: Hai Ngo.

In total, 14 sections of 14 different streams with lengths varying from 320 to 1400 m (see Table 1) were surveyed. Thereof, two streams were in Phong Dien NR (Phong Dien District), at elevations between 43 and 90 m a.s.l, eight streams were within Sao La NR (A Luoi District) at elevations between 176 and 820 m a.s.l and four streams were within Bach Ma NP (Nam Dong District) at elevations between 105 and 269 m a.s.l. Each stream was repeatedly surveyed in intervals of several days. At each point of investigation, the team consisted of 2–4 persons. Coordinates and elevations for each captured individual were recorded with a GPS Garmin 64. These streams were selected based on information about the presence of *P. cocincinus* obtained during previous surveys and interviews with local people. Lengths of stream sections were dependent on habitat suitability and accessibility.

All encountered individuals were captured, individually marked with a permanent pen (Edding Eraser) and released at the same spot after taking measurements (Fig. 2B, C). This marking technique has the advantage of being non-invasive, not affecting the animals, inexpensive and enables the short-term identification of animals, while marking lasts until the next shedding of the animals (for details see Ngo et al. 2016). Each spot was marked by a label made of waterproof paper to identify exact positions of captured and recaptured animals. It was observed that animals occupied previous perches after marking, indicating that capturing does not affect the behaviour and perch choice of animals. Generally, individuals of all ages and sexes were found in a likewise manner. To estimate

Table 1. Survey sites in Thua Thien Hue Province, central Vietnam.

Stream	District	*Physignathus cocincinus*	Elevation (m. asl)	Length (m)	Habitat type
1	Phong Dien	Present	44–90	1,160	Primary forest
2	Phong Dien	Present	43–75	1,300	Primary forest
3	A Luoi	Present	706–780	320	Secondary forest
4	A Luoi	Present	720–820	500	Secondary forest
5	A Luoi	Present	623–770	420	Secondary forest
6	A Luoi	Present	176 – 250	950	Secondary forest
7	A Luoi	Present	179–214	700	Secondary forest
8	Nam Dong	Present	129–179	1,400	Primary forest
9	Nam Dong	Present	173–269	1,300	Primary forest
10	Nam Dong	Present	111–145	1,000	Secondary forest
11	Nam Dong	Present	105–129	460	Secondary forest
12	A Luoi	Absent	550-740	1,000	Secondary forest
13	A Luoi	Absent	650-875	450	Secondary forest
14	A Luoi	Absent	690	–	Secondary forest

population sizes, a non-invasive "Capture-recapture Method" was applied using both the "Lincoln-Peterson Index" in case of one-time mark and recapture event and the "Schnabel Index" in case of several mark and recapture events (e.g. Caughley 1980; Schlüpmann and Kupfer 2009; Smith and Smith 2009). The Petersen-Lincoln estimation requires several assumptions, namely a closed population, the same capture probability for all animals and that markings neither affect animals nor will be lost between sampling. Surveys were repeated along each site within the timeframe of only three days, as migration events were not expected to occur due to the sedentary behaviour of *P. cocincinus*. Based on the reasons mentioned above, it was also expected that the assumptions on markings and capture probability would be fulfilled. Estimated population sizes only refer to survey sites and might not be representative for the entire population of the species in Central Vietnam.

To assess the population structure of *P. cocincinus*, lizards were categorised into three age classes based on the snout-vent length (adult with SVL > 140 mm, sub-adult with 100 mm < SVL ≤ 140 mm and juvenile with SVL ≤ 100 mm). As sexual dimorphism is only expressed in adult *P. cocincinus* (e.g. presence of well-developed nuchal and dorsal crests in adult males; see Fig. 2C, D), accurate sex determination of living animals thus could only be performed in mature individuals. To test for differences in population structure and frequency of snout-vent length between April and June, 2016 and 2017, a c^2 test with $\alpha = 0.05$ was applied. Statistical analysis was carried out with the SPSS software, version 16.0 (SPSS Inc., Chicago).

Threat evaluation

In order to assess levels of harvesting and use of the Asian Water Dragon in Thua Thien Hue Province, 21 hunting groups were interviewed between February and October 2016, including six groups from Phong Dien District, seven groups from A

Luoi District and eight groups from Nam Dong District. Each group contained two or three lizard hunters. Some rapid surveys were also conducted in local markets and restaurants in district towns of Phong Dien, A Luoi, Nam Dong and in Hue City to obtain evidence of local trade and consumption of lizards. Single impacts on local sub-populations were ranked according to severity as "low" defined as being observed only once or less, "medium" defined as being observed several times or "high" defined as being recorded frequently. Furthermore, several internet platforms were screened to obtain an overview of the availability, demand, prices and evidence of trade in the species. Since the species is listed on Annex D of the Council Regulation (EC) No 338/97, which requires an import notification at EU border customs, retrospective data were obtained for the recorded imports of *P. cocincinus* from Vietnam into the EU from 2010 to 2016 from the UNEP-WCMC CITES trade database (UNEP-WCMC 2017). Taking into account that CITES trade database records might be incomplete (D'Cruze and Macdonald 2017) and considering this dataset only represents imports into the EU and does not encompass imports into other states, this data however provides a rough impression on current trade levels.

Results

Population status

During the present study, *P. cocincinus* was found along 11 of 14 investigated sites within three districts of Thua Thien Hue Province. In 2016, the authors only surveyed A Luoi District and recorded a similar number of individuals of *P. cocincinus* in April and June along all five sites, counting 97 and 95 individuals, respectively. In 2017, a total of 167 animals (thereof 31 adults) were captured in April in Phong Dien and Nam Dong districts and 172 individuals were observed in June in all three districts, of which 28 were adults. Higher fluctuations in population sizes were observed between the two consecutive surveys in April and June 2017 in Phong Dien and Nam Dong than those in the year before in A Luoi. The estimated total population size at the survey area was about 250 animals in April 2017. Even though two additional sites in A Luoi District (viz. five sites in total) were included in the estimation, the estimated population size decreased to 233 individuals in June 2017 (Table 2). With respect to the sub-population in Phong Dien District, site 2, the estimated population size was distinctly higher in April than in June 2017 (124 vs. 87 individuals, respectively). In Nam Dong District, transect 9, the number of observed individuals also significantly decreased from 25 individuals in April to 2 individuals in June and only 3 individuals were recorded along transect 11 in June 2016. The authors failed to observe any adult specimens of *P. cocincinus* in the transect 8 in Nam Dong District in June, whereas the species had been earlier recorded in April 2017 (Table 2).

In total, most individuals were encountered in Phong Dien District, where the highest incidence of adult individuals was also recorded compared to the other two

Table 2. Summary of observed individuals as well as densities and population size estimates ($\hat{N}$) of *Physignathus cocincinus* in Thua Thien Hue Province, central Vietnam in April and June, 2016 and 2017. D: Density; ind: individuals; Asterisks indicate missing data.

District	Phong Dien		A Luoi					Nam Dong				Total
Stream	1	2	3	4	5	6	7	8	9	10	11	
April-2016												
Total (observed)	*	*	4	4	6	25	21	*	*	*	*	60
Mature (obs.)	*	*	1	4	0	7	2	*	*	*	*	14
D[ind/100 m of stream]	*	*	1.25	0.8	1.43	2.63	3.0	*	*	*	*	1.98
$\hat{N}$	*	*	6	6	12	35	38	*	*	*	*	97
June-2016												
Total (observed)	*	*	4	5	5	22	22	*	*	*	*	58
Mature (obs.)	*	*	3	2	1	5	0	*	*	*	*	11
D[ind/100 m of stream]	*	*	1.25	1.0	1.19	2.32	3.14	*	*	*	*	1.98
$\hat{N}$	*	*	5	9	6	42	33	*	*	*	*	95
April-2017												
Total (observed)	13	86	*	*	*	*	*	26	25	17	*	167
Mature (obs.)	0	18	*	*	*	*	*	5	6	0	*	29
D[ind/100 m of stream]	1.12	6.62	*	*	*	*	*	1.86	1.92	1.7	*	2.64
$\hat{N}$	*	124	*	*	*	*	*	74	52	*	*	250
June-2017												
Total (observed)	33	67	*	*	*	25	22	*	2	20	3	172
Mature (obs.)	8	17	*	*	*	2	1	*	0	0	0	28
D[ind/100 m of stream]	3.84	5.15	*	*	*	2.63	3.14	*	0.15	2.0	0.65	2.51
$\hat{N}$	56	87	*	*	*	35	24	*	*	30	*	232

sub-populations. The mean density of *P. cocincinus* along suitable stream transects was estimated to be around 25–26 individuals per km of transect. By comparing different habitat sites, the highest abundance of *P. cocincinus* was found in April 2017 at site 2 in Phong Dien District (about 6.6 individuals per 100 m stream length). In A Luoi District, being situated at elevations of 623–820 m, densities ranged from 0.8 to 1.4 individuals per 100 m stream length along sites 3, 4 and 5. The authors failed to observe any lizards along the other three sites, namely 12, 13 and 14, in April and June 2017. In comparison, densities along transects of lower elevations (from 49–269 m), even though in a slightly disturbed habitat, were about or higher than two individuals per 100 m stream length during at least two surveys (sites 6 and 7).

Comparing the data achieved in the different months, the investigated population of *P. cocincinus* in Thua Thien Hue Province consisted mainly of juveniles (139 individuals) in April, followed by sub-adults, adult males and adult females (60 %, 19 %, 11 %, 10%, respectively; Fig. 3A). In June, the population structure significantly differed ($c^2 = 50.401$; df = 3; $a < 0.001$), with sub-adults (113 individuals) constituting the major proportion, followed by juveniles, adult females and adult males (50 %, 33 %, 10 %, 7 %, respectively; see Fig. 3A). Frequency histograms of SVL (Min–Max = 42.4–260 mm) showed a tendency for a monthly variation in the presence of age classes of *P. cocincinus* from Thua Thien Hue Province ($c^2 = 77.87$; df = 6; $a < 0.001$). Indi-

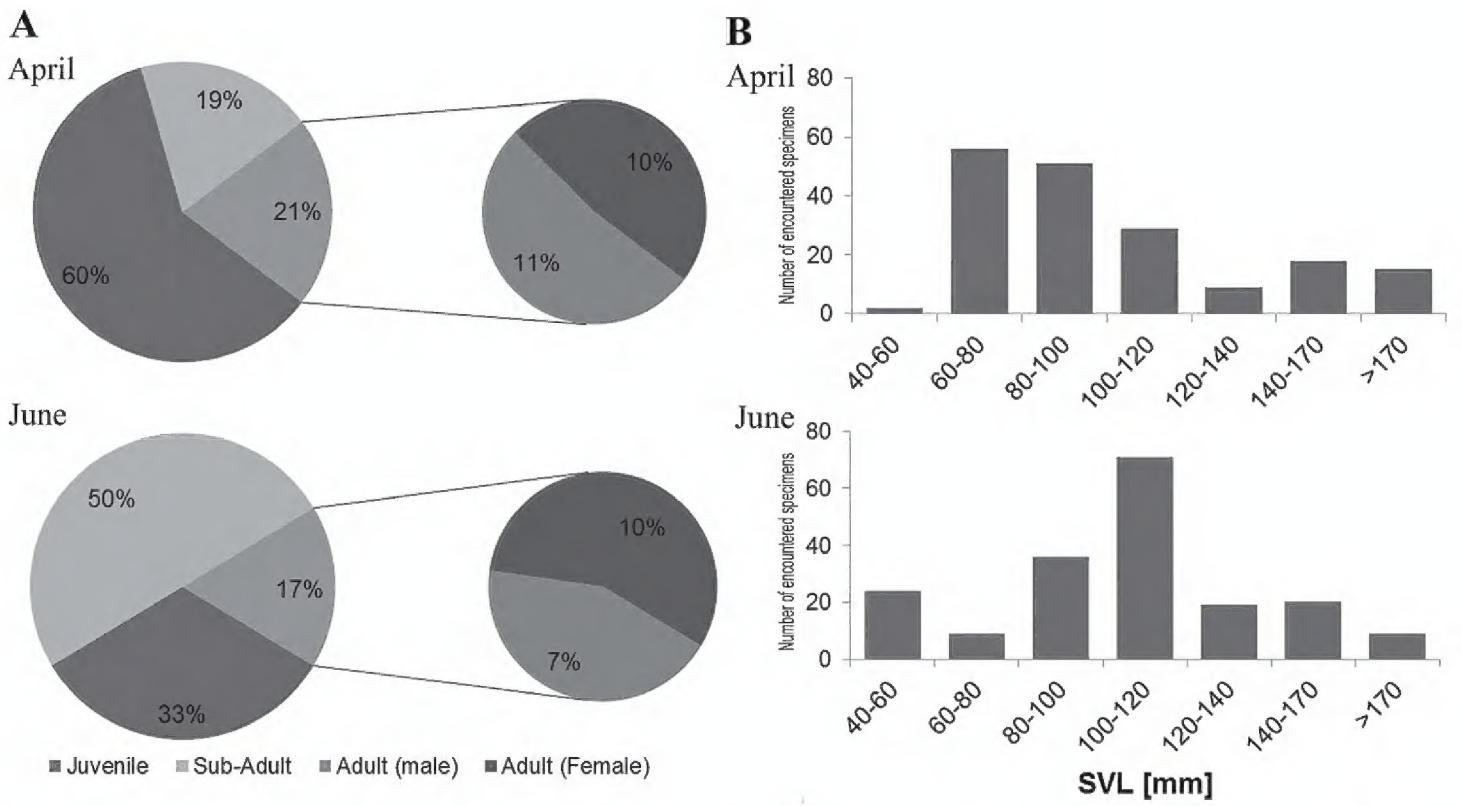

Figure 3. Population structure of *Physignathus cocincinus* from Thua Thien Hue Province, central Vietnam (April vs. June, respectively); B. Frequency histogram of snout-vent length of *P. cocincinus* for the months April and June, 2016 and 2017.

viduals with the shortest SVL (40–60 mm) were mostly found in June, while juveniles with higher SVL (60–100 mm) and adults accounted for a larger number in April. Sub-adults with SVL larger than 100 mm were observed more frequently in June (Fig. 3B).

Threat evaluation

According to interviews with local hunters and the authors' own observations, wild *P. cocincinus* populations are affected by negative anthropogenic impacts in all investigated districts (Table 3). In two of three districts, namely A Luoi and Nam Dong, the total impact is even considered to be high. Harvesting of the Asian Water Dragon has been frequently recorded by the team in all surveyed districts of Thua Thien Hue Province. Interviews with 21 local hunter groups in the remote villages within the species distribution range revealed that adult lizards are heavily collected by hand and/or with traps (Fig. 4A) from February to October, while the number of captured animals is usually highest in May and June. With respect to quantities, a total of about 1,000 kilograms of animals collected by hunters was recorded from the three study sites in Thua Thien Hue Province in 2016, which corresponds to more than 2,000 individuals considering a mean mass of 450 g. Eggs of *P. cocincinus* were also collected and soaked in rice wine for traditional medicine (Fig. 4D). It was regularly recorded that captured animals were sold in local markets and then finally were transferred to local restaurants as food (Figs. 4B and C). The price of living animals was approximately 250,000 Vietnam dong (about $12) per kilogram in remote districts and fetching

Table 3. Impacts on *Physignathus cocincinus* at study sites based on interview data and own observations.

District	Trapping/ hand collection	Use for traditional medicine	Consumption in restaurants	Incidence on local markets	Habitat degradation	Total impact
Phong Dien	High	Low	Medium	High	Low	Medium
A Luoi	High	–	Medium	High	High	High
Nam Dong	High	Low	High	High	High	High

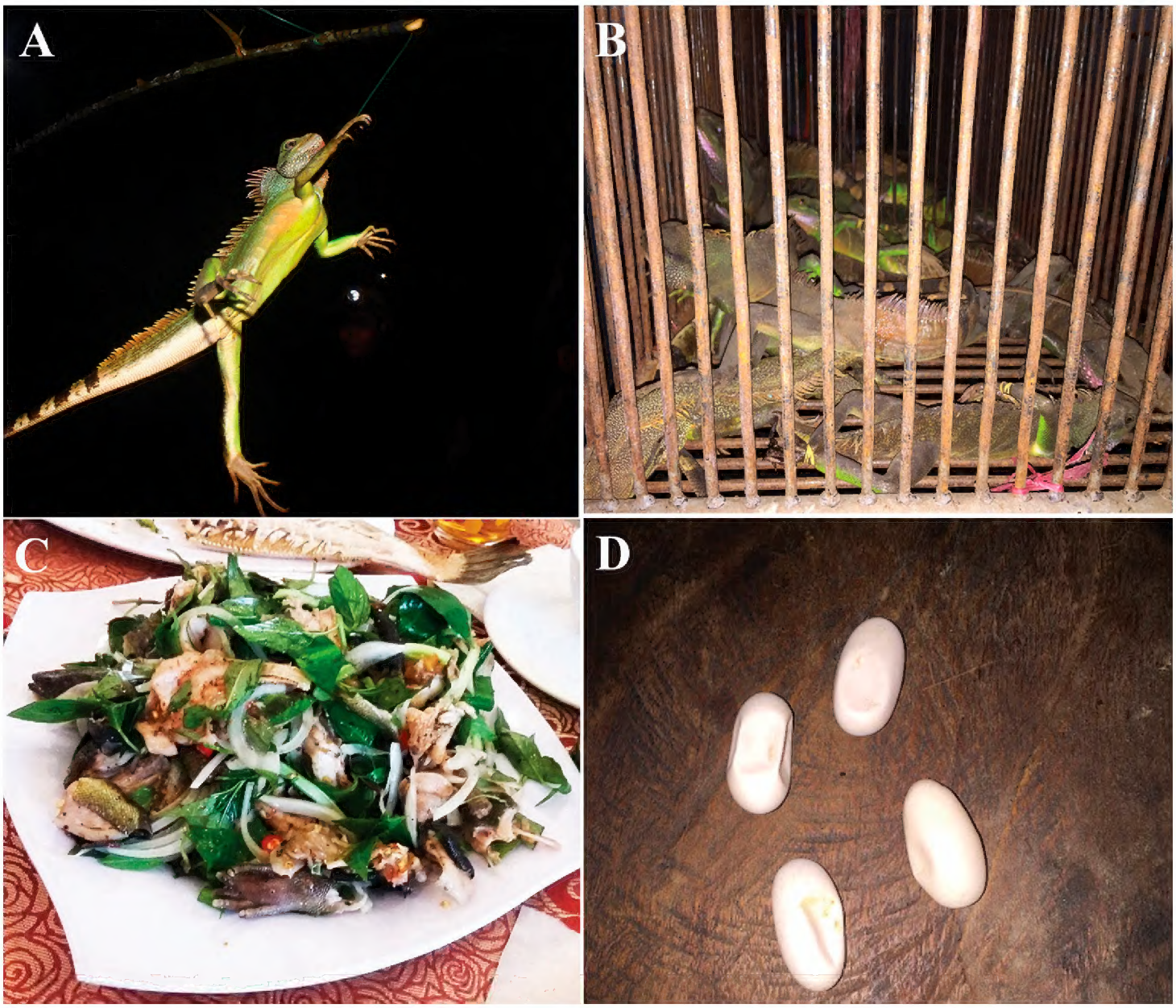

Figure 4. Threats to *Physignathus cocincinus* in Thua Thien Hue Province: **A** A trapped individual in Nam Dong District **B** Specimens collected for food in Hue City **C** The Asian Water Dragon served as food in a restaurant in Hue City **D** Eggs of *P. cocincinus* preserved in alcohol in Nam Dong District.

up to 450,000 Vietnam dong (about $20) per kilogram in restaurants in Hue City. In addition, the Asian Water Dragon became very popular in local pet markets due to its striking appearance. *P. cocincinus* was frequently observed being offered for sale for prices ranging from 150,000 (about $7) to 450,000 Vietnam dong (about $20) / individual, depending on size and/or colouration in local pet shops and on several Vietnamese internet platforms, such as Facebook from Hanoi and Ho Chi Minh City.

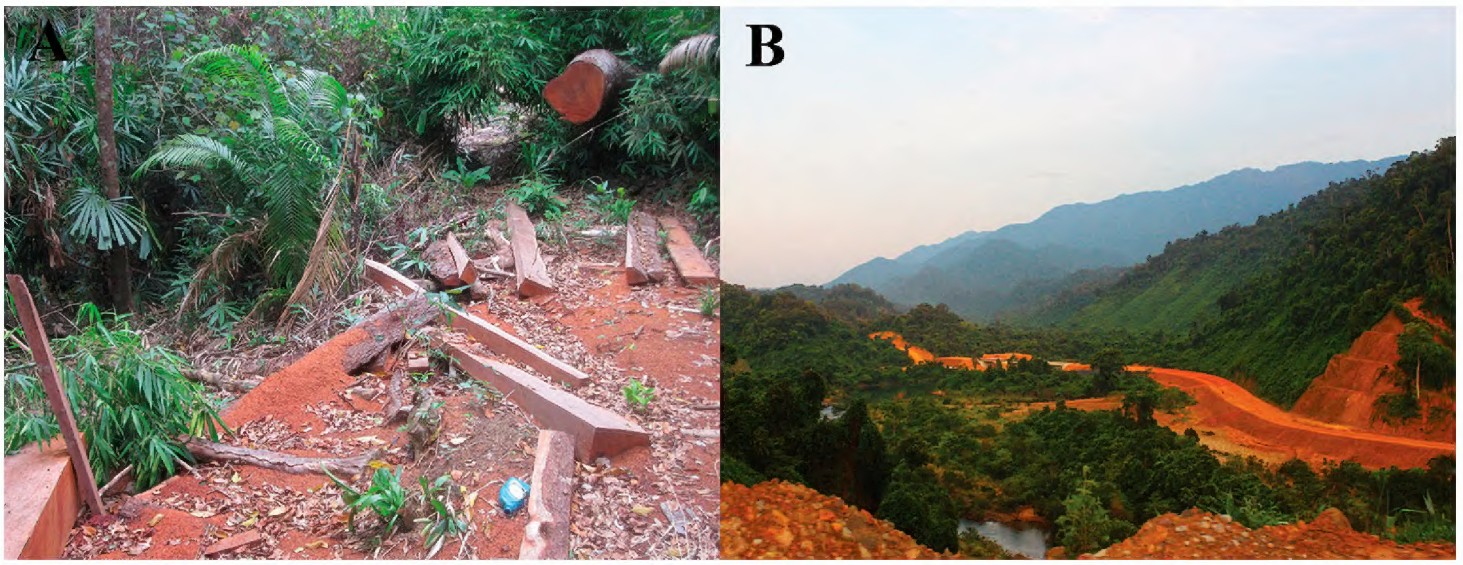

Figure 5. Threats to *Physignathus cocincinus* in Thua Thien Hue Province: **A.** Illegal timber logging in Nam Dong District; **B.** Building a highway from Nam Dong to A Luoi District.

With respect to the international trade in the species, a total of 43,100 specimens have been officially exported by Vietnam into the EU between 2010 and 2016 according to the UNEP-WCMC trade database. Thereof, most specimens had an unknown origin and some were stated to be "wild caught", while the purpose was "for commercial use" in any case. Germany was the country with by far the most imports. It can be assumed that the majority of exported specimens with unknown origin are actually wild individuals, since there is no knowledge about breeding facilities. According to interviews with locals, there have been some people keeping and rearing *P. cocincinus* to supply local restaurants for a short period. However, these facilities were recently closed, because it is allegedly more convenient to collect wild animals than to spend time and efforts in breeding them, as long as animals can be found in the wild.

It was found that habitat loss and habitat alterations, such as road building and illegal timber logging (Figs. 5A and B), are further critical threats to *P. cocincinus* in Thua Thien Hue Province. For the building of highways from Nam Dong to A Luoi District, huge parts of the forest have been cleared, which resulted in the fragmentation of forest streams, thus affecting stream-adapted species like *P. cocincinus*. The construction of roads furthermore has facilitated illegal logging, because accessibility of forested regions has significantly increased and now almost every area within Bach Ma NP and Saola NR can be easily reached. Phong Dien District is the only one of the three investigated sites, which is hardly affected by habitat degradation.

Discussion

In order to manage the wild populations of the Asian Water Dragon properly and to implement conservation measures accordingly, the assessment of its population status, abundance and distribution is important. In total, the estimated population size probably does not encompass all occurrences of *P. cocincinus* in Thua Thien Hue Province, however due to the strong association of the species with small freshwater streams,

which only represent small areas of the Province, it can be assumed that the total population is not disproportionately higher. A detailed further assessment on the availability of suitable habitats would be helpful.

Generally, *P. cocincinus* was found in monthly densities of 2.6 and 2.5 individuals per 100 m in April and June, 2017, respectively. However, three stream transects (3, 4 and 5) in A Luoi District, located at higher elevations (623–820 m), revealed a constantly lower density of *P. cocincinus* than found in other streams, although the habitat was not disturbed. It seems that not only hunting activities, but also elevation and habitat quality of each stream, might influence the abundance of the species. Recently, van Schingen et al. (2015) explained the abundance of the Crocodile Lizard (*Shinisaurus crocodilurus*), another semi-aquatic lizard occurring in northern Vietnam, to mainly depend on the stream properties and water quality that varied along elevation gradients. Thus, these hypotheses explaining abundances of *P. cocincinus* need to be tested in further studies.

Regarding the sex ratio of the species, investigations in 2016 and 2017 showed that the number of adult males was slightly higher than that of adult females in April. However, adult females were observed more frequently in June, which might be an indication for targeted harvest. Most of the local hunters, who have been interviewed, preferred collecting adult males of *P. cocincinus*, because of their bigger size compared to adult females, an important aspect in terms of food consumption. There was a significant difference in age structure in *P. cocincinus* between April and June, with juveniles accounting for the dominant percentage in April and sub-adults being predominant in June. This trend can be explained by the fact that juveniles of *P. cocincinus* reach the sub-adult stage relatively fast (after only two months), indicating that the survival rate is relatively high in the species. Overall estimates of the population size of *P. cocincinus* in the survey areas within Thua Thien Hue Province, central Vietnam, revealed that the population remained relatively stable between April and June with 250 to 232 individuals respectively in 2017. This trend was constantly observable at each survey site, except for the sub-population in Nam Dong District with a distinct decline in encountered individuals from April to June. This might be explained by the fact that the population in Nam Dong District is heavily affected by hunting activities. Reed et al. (2003) suggested that a population size of at least 3,000–7,000 mature individuals is required to maintain stable populations over a long time period. Thus, an ongoing decline in the number of mature individuals could negatively impact the genetic diversity and reproductive capacity of *P. cocincinus* in Thua Thien Hue Province. The compilation of impacts on *P. cocincinus* at different sites indicates that the total impact is "high" in A Luoi and in Nam Dong and only "medium" in Phong Dien. Accordingly, sizes of sub-populations were smaller and lower numbers of adult individuals were recorded in A Luoi and Nam Dong than those in Phong Dien. These findings indicate that anthropogenic impacts negatively affect population sizes. Furthermore, Phong Dien was the only site with hardly any habitat degradation, which indicates the potential and value of intact habitats to buffer harvesting activities.

Conclusions

In total, several critical threats to the population and habitat of *P. cocincinus* were recorded in Thua Thien Hue Province, namely harvesting for food consumptions and to supply trade, as well as habitat fragmentation through road construction and timber logging. It is assumed that similar impacts are certainly to be observed in other areas in Vietnam. Besides local use of the species, the recorded imports of more than 43,000 animals from Vietnam into the EU for commercial use during recent years indicate an increasing international interest in the species. Most of those specimens had an "unknown" origin. According to interviews with local people involved in the trade in *P. cocincinus*, there are no attempts at breeding of the species in captivity, since harvesting from the wild is currently the most economic way. Thus, it is expected that most of the reported imports will represent wild individuals. In addition, this data represents only the tip of the iceberg of actual international trade levels in the species, since only imports into the EU are recorded. In addition to the international trade, the species is also harvested in large amounts for national use. According to these high levels of exploitation, it is recommended that continuous monitoring of wild populations be undertaken in order to warrant the sustainable use of the species. It is also recommended to extend monitoring activities on further populations in the North and South of Vietnam. Moreover, captive breeding could be an alternative, as currently undertaken at the Me Linh Station for Biodiversity in northern Vietnam and in Phong Dien District as well as in Hue City in Central Vietnam. Such breeding programmes could later be transferred to local communities to reduce the pressure on wild populations and supply the high demand for the species. The listing of the species in CITES Appendix III and the establishment of a sustainable export quota could support a shift from the use of wild harvested specimens to captive bred ones. Furthermore, it is herewith recommended to improve conservation measures in the natural habitats in collaboration with the local authorities to enable the long-term persistence and sustainable use of the species.

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References

Caughley G (1980) Analysis of Vertebrate Populations. John Wiley, Chichester, 234 pp.

Cox MJ, Van Dijk PP, Nabhitabhata J, Kumthorn T (1998) A photographic guide to snakes and other reptiles of Peninsular Malaysia, Singapore and Thailand. Ralph Curtis Publishing: 1–144.

D'Cruze N, Macdonald DW (2017) An update on CITES live confiscations, in response to Lopes et al. (2017). Nature Conservation 21: 163–166. https://doi.org/10.3897/natureconservation.21.20421

Grismer LL, Neang T, Chav T Grismer JL (2008a) Checklist of the amphibians and reptiles of the Cardamom region of Southwestern Cambodia. Cambodian Journal of Natural History 2008(1): 12–28.

Grismer LL, Neang T, Chav T, Wood Jr PL, Oaks JR, Holden J, Grismer JL, Szutz TR, Youmans TM (2008b) Additional amphibians and reptiles from the Phnom Samkos Wildlife Sanctuary in Northwestern Cardamom Mountains, Cambodia, with comments on their taxonomy and the discovery of three new species. The Raffles Bulletin of Zoology 56(1): 161–175.

Ministry of Science and Technology, Vietnam Academy of Science and Technology (2007) Vietnam red data book. Part I. Animals. Science and Technics Publishing House, 515 pp.

Nabhitabhata J, Chan-ard T, Chuaynkern Y (2000) Checklist of amphibians and reptiles in Thailand. Office of Environmental Policy and Planning, Bankok, 152 pp.

Ngo HN, Ziegler T, Nguyen TQ, Pham CT, Nguyen TT, Le MD, van Schingen M (2016) First population assessment of two cryptic Tiger Geckos (Goniurosaurus) from northern Vietnam: Implications for conservation. Amphibian & Reptile Conservation 10(1): 34–45.

Nguyen BL, Nguyen VL, Pham QV, Vu TL, Tran TH (2013) Statistical Yearbook of Vietnam – General Statistics Office. Statistical Publishing House, Hanoi.

Nguyen SV, Ho CT, Nguyen TQ (2009) Herpetofauna of Vietnam. Chimaira, Frankfurt, 768 pp.

Reed DH, O'Grady JJ, Brook BW, Ballou JD, Frankham R (2003) Estimates of minimum viable population sizes for vertebrates and factors influencing those estimates. Biological Conservation 113: 23–34. https://doi.org/10.1016/S0006-3207(02)00346-4

Schlüpmann M, Kupfer A (2009) Methoden der Amphibienerfassung – eine Übersicht. Zeitschrift für Feldherpetologie 15: 7–84.

Smith MA (1935) The fauna of British India, including Ceylon and Burma. Vol. II. Sauria. Taylor and Francis, London, 8, 440 pp.

Smith TM, Smith RL (2009) Ökologie. Pearson Studium, München.

Stuart BL, Emmett DA (2006) A collection of amphibians and reptiles from the Cardamom Mountains, Southwestern Cambodia. Fieldiana Zool. N.S. (109): 1–27.

Stuart BL, Sok K, Neang T (2006) A collection of amphibians and reptiles from hilly Eastern Cambodia. Raffles Bulletin of Zoology 54(1): 129–155.

Suzuki D, Fuse K, Aizu M, Yoshizawa S, Tanaka W, Araya K, Praxaysombath B (2015) Reptile diversity in food markets in Laos. Current Herpetology 34(2): 112–119. https://doi.org/10.5358/hsj.34.112

Taylor EH (1963) The lizards of Thailand. The University of Kansas Science Bulletin 44: 687–1077. https://biodiversitylibrary.org/page/3280261

Traill LW, Bradshaw CJA, Brook BW (2007) Minimum viable population size: A meta-analysis of 30 years of published estimates. Biological Conservation 139: 159–166. https://doi.org/10.1016/j.biocon.2007.06.011

Uetz P, Hošek J (2017) The Reptile Database. http://www.reptile-database.org

UNEP-WCMC (2017) CITES Trade Database. http://trade.cites.org/ [Viewed on 03 September 2017]

van Schingen M, Pham CT, An HT, Nguyen TQ, Bernardes M, Bonkowski M, Ziegler T (2015) First ecological assessment of the endangered crocodile lizard *Shinisaurus crocodilurus* Ahl, 1930 in Vietnam: Microhabitat characterization and habitat selection. Herpetological Conservation and Biology 10: 948–958.

Ziegler T (2002) Die Amphibien und Reptilien eines Tieflandfeuchtwald-Schutzgebietes in Vietnam. Natur & Tier Verlag, Münster, 342 pp.

Ziegler T, Rauhaus A, Mutschmann F, Dang PH, Pham CT, Nguyen TQ (2016) Building up of keeping facilities and breeding projects for frogs, newts and lizards at the Me Linh Station for Biodiversity in northern Vietnam, including improvement of housing conditions for confiscated reptiles and primates. Der Zoologische Garten 85: 91–120. https://doi.org/10.1016/j.zoolgart.2015.09.001